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13. ABSTRACT (Maximum 200 words)

ABSTRACT (Continue on reverse side if necessary and identify by block number)

The work accomplished during the last six-month period (1 Apr 84 - 30 Sep 84) is reported below.

Work accomplished during the first six months is given in the Interim Technical Report (1 Oct 83 - 31 Mar 84), copy attached.

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(Continued)

The Nb-Al system has been used as a model system to study the phase transformation in metastable alloys by using the superconductivity of the A15 phase to determine the composition with the highest Tc, and the lattice constant to determine the average composition. By depositing Nb-Al in a phase spread orientation onto substrates at 0°C, the bcc structure has been extended to about 40 at % (well above the equilibrium 9%). Subsequent annealing experiments transformed the bcc phase to A15. It was found that stoichiometric Nb_3Al could be formed in the A15 phase well above the concentration of the Al at equilibrium which is 22%, when the slopes of the free energy curves of the respective phases are equal. Thus the particular shape of the (free) energy curves is important and can determine the composition of the precipitated phase.

Nb-Sn-Ga alloys were prepared and studied as model systems to investigate the influence of third element additions on the normal and superconducting properties of alloyed Nb_3Sn phases. In spite of a decrease in the density of states at the Fermi level with increasing Ga content and upper critical field, B_{c2} was found to increase. B_{c2} maximized at 1 to 1.5 at % Ga for reaction temperatures at 700°C. High critical fields up to 31.5 T (at T=4.2K) have been achieved.

Additions of Nb, Ta, Sn, and Pt to V_3Ga were studied by co-deposition of the elements along with V and Ga. The accepted model of spin-orbit scattering predicts that substantial increases in critical field should have been observed. However, no increase was seen with any of the above additions. Further work is need to rule out unusual microstructural features before looking for a basic breakdown of the models of spin-orbit scattering.

New ion sources have been developed with high performance at low energy (1-100 ev) and high flux (.2 - 1.0 ma/cm^2). The low energy prevents damage to ordered compounds and the high flux is desirable to match the arrival rate of evaporated metal atoms. The ion beam has been used in test runs to prepare NbN_xC_y, and in the hydrogen doping of amorphous Si. Future potential applications which have been identified include: (a) other compound syntheses (nitrides, carbides, oxides and borides of most elements); (b) surface mobility enhancement, including grain size control, internal strain modification, removal of impurities, gases, and low-temperature growth of ordered compounds; (c) interface modification of compounds (ion assisted wetting); (d) metastable high-pressure high-temperature phase formation.

ANNUAL TECHNICAL REPORT

FOR

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Contract No. F49620-82-C-0014

1 October 1983 - 30 September 1984

SUPERCONDUCTING THIN FILMS, COMPOSITES AND JUNCTIONS

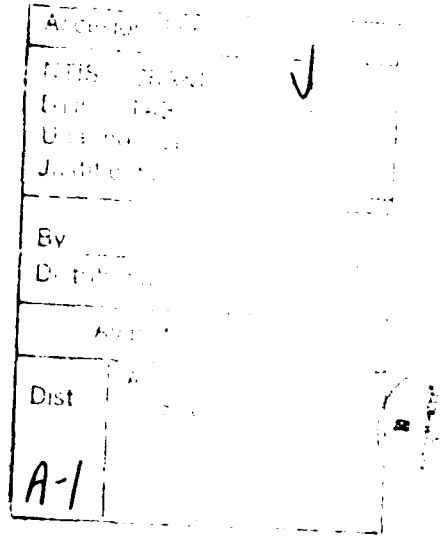
By

Professor T. H. Geballe
Principal Investigator

Department of Applied Physics
Stanford University
Stanford, California 94305

G. L. Report 3783

October 1984



20. (Continued)

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PUBLICATIONS
(1 Apr 84-30 Sep 84)

1. "Response to 'Comment on Tunneling $\alpha^2F(\omega)$ as a Function of Composition in A15 NbGe'" by B. R. Sood, by K. E. Kihlstrom and T. H. Geballe, Phys Rev B, 27, 3082 (1983).

2. "Phase Transformations in Metastable Nb-Alloys, by R. Bormann, D.-Y. Yu, R. H. Hammond, A. Marshall, T. H. Geballe, to be published in Proceedings of the 5th International Conference on Rapidly Quenched Metals, Wurzburg, FRG, September 1984.

3. "Superconducting Materials," by M. R. Beasley and T. H. Geballe, Physics Today, pp 60-68, October 1984

4. "Critical Magnetic Field of V_3Ga Thin Films with Third Element Additions," by P. M. Tedrow, J. E. Tkaczyk, R. Meservey, S. J. Bending, and R. H. Hammond. Proceedings of 1984 Applied Superconductivity Conference, San Diego to be published in IEEE Transactions on Magnetics, 1985.

5. "A15 Nb-Sn Tunnel Junction Fabrication and Properties," by D. A. Rudman, F. Hellman, R. H. Hammond, and M. R. Beasley, J. Appl. Phys. 55, 3544 (1984).

6. "Phase Relationships and Superconducting Properties of Ternary Systems Used in the Bronze Process, by R. Bormann, Adv Cryogenic Engineering 30, 659 (1984).

7. "Towards an Understanding of the Limits of Superconductivity," by T. H. Geballe, presented at the Distinguished Lecture Series, N. Mexico, October 1983.

Persons working on contract during the period
1 April 1984 - 30 September 1984

Hammond, Robert H.	Senior Research Associate
Hellman, Frances	Ph.D. expected Winter 1985
Mael, David	Ph.D. expected Summer 1985
Brouccard, Phillip	Ph.D. expected Summer 1985
Park, Sung	Ph.D. expected Summer 1986
Kent, Andrew	Ph.D. expected Summer 1986

Visitors and Seminars

1. George Mozurkewich, Physics Department, UCLA
"Charged density waves"
April 5, 1984

2. Gerd Bergmann, IFF der KFA Julich, West Germany
"Weak localization in thin films -- a time-flight experiment with conduction electrons"
April 17, 1984

3. Hidetoshi Fukuyama, Institute for Solid State Physics, University of Tokyo
April 17, 1984

4. Masaki Suenaga, Brookhaven National Laboratory, Upton, NY
May 16, 1984

5. V. Ambegaokar, Cornell University and Institute for Theoretical Physics, UC Santa Barbara
"Microscopic theory of shot noise in the Josephson effect"
May 17, 1984

6. G. Sawadsky, University of Croningen, The Netherlands
"Electron spectroscopy studies of the electronic structure of dilute transition metal alloys"
May 24, 1984

7. H. Poppa, NASA, Ames Research Center
"Physics and chemistry of UHV deposited metal particles and clusters"
June 7, 1984

8. J. E. Kunzler, AT&T Bell Laboratories
June 25, 1984

9. Jean-Paul Maneval, ENS Physique des Solides, Paris, France
August 1984

10. Atsushi Kome, Institute of Materials Science, University of Tsukuba, Ibaraki, Japan
August 1984

11. William McLean, Rutgers University
September - November 1984

12. H. Weinstock, AFOSR
September 6, 1984

13. R. Flukiger, Institute fur Technische Physik, Karlsruhe, FRG
September 13, 1984

Visitors and Seminars (Continued)

14. David F. Moore, Cambridge, England
September 14, 1984

15. Rudi Bormann, Universitat Gottingen, FRG
September 15-30, 1984

16. Tord Claesson, Chalmers University of Technology, Gothenburg, Sweden
September 17-21, 1984

17. Alex Braginski, Westinghouse Research Laboratories, Pittsburgh, PA
September 17, 1984

18. Oystein Fischer, E.T.H., Switzerland
September 18-19, 1984

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Member, Committee for the American Physical Society International Prize for New Materials

Member, Advisory Board of the Miller Institute for Basic Research in Science

Member, Program Committee for meeting on "Materials and Mechanisms of Superconductivity" in Ames, Iowa, May 29-31, 1985

Scientific projects are being carried out in close collaboration with industry

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J. Boyce, Xerox Corporation, Palo Alto, California

J. H. Wernick, Bell Laboratories, Murray Hill, New Jersey
J. M. Rowell, Bell Laboratories, Murray Hill, New Jersey
C. W. Hull, Bell Laboratories, Murray Hill, New Jersey
M. Hong, Bell Laboratories, Murray Hill, New Jersey
W. P. Lowe, Bell Laboratories, Murray Hill, New Jersey

R. Greene, IBM, San Jose, California

J. Harper, IBM, Yorktown Heights, New York

A. Braginski, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

A. Green, Naval Research Lab, China Lake, California
V. Rehn, Naval Research Lab, China Lake, California

New discoveries, inventions or patent disclosures

None

INTERIM TECHNICAL REPORT

FOR

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Contract No. F49620-82-C-0014

1 October 1983 - 31 March 1984

SUPERCONDUCTING THIN FILMS, COMPOSITES AND JUNCTIONS

By

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Stanford University
Stanford, California 94305

G. L. Report 3722

April 1984

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A-15 Structures
Metastable phases

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The first specific heat measurements on artificially layered superconducting composite structures have been made. Small sample calorimetry has been used to measure the specific heat of NbZr multilayers with a bi-layer period varying from 32 Å to 429 Å (to a sample thickness of 1.5 um) over the temperature range from 1.5 to 20K. The normal state parameters agree with the presence of an interface of an Nb Zr alloy in agreement with earlier X-ray results. The behavior of the thermally measured transition into the superconducting state and the magnitude of the associated specific heat increase also agree with the

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tri-layer model.

The presence of oxygen during the growth of NbGe films is known to be essential for obtaining A-15 structures with the highest known superconducting transition temperatures. Experiments have been initiated to discover the role that oxygen plays. They show surprisingly that no oxygen is present in the films upon removal from the evaporator. The non-presence of oxygen has been found to eliminate a number of possible models. Evidence has been obtained for a model in which the oxygen is present in the film during growth at high ~ 900C, but that it diffuses out as the film cools down. Techniques have been introduced using a thin layer of the yttrium as a getter for the oxygen, combined with Auger profiling, in order to obtain the evidence.

The use of added thermally oxidized metallic coatings on single-crystal Nb surfaces has been found to modify the tunneling parameters systematically. High quality $Nb/ZrO_x/Pb$ and $Nb/TiO_x/Pb$ Josephson tunnel junctions based on single crystal niobium thin films coated with either Zr or Ti have been fabricated by thermal oxidation. The specific capacitance of these junctions has been determined from Fiske modes and Josephson diffraction patterns and found to be considerably less than found for oxide surfaces prepared upon polycrystilline pure Nb surfaces in a similar way. The ZrO and TiO barriers offer new possibilities for fabricating all refractory niobium Josephson junction devices.

PUBLICATIONS

1. "The Science of Useful Superconductors – and Beyond," by T. H. Geballe, IEEE Trans. Mag. MAG-19, (1983).

2. "Phase Stability of A15 Nb-Sn," by F. Hellman, D. A. Rudman, R. H. Hammond and T. H. Geballe, Bull. Am. Phys. Soc., 28, 262 (1983).

3. "The Effect of Annealing on Sputtered Multilayers of NbZr," by P. R. Broussard, W. P. Lowe and T. H. Geballe, Bull. Am. Phys. Soc., 28, 298 (1983).

4. "Specific Heat of Thin Film Amorphous Molybdenum Based Alloys," by D. Mael, W. L. Carter, S. Yoshizumi and T. H. Geballe, Bull. Am. Phys. Soc., 18, 263 (1983).

5. "Annealing Effects on Superconductivity of Amorphous Vapor Quenched $Mo_{1-x}Ge_x$ (x = 0.35)," by S. Yoshizumi and W. L. Carter, Bull. Am. Phys. Soc. 28, 263 (1983).

6. "Tunneling Properties of Zr:O_x as Artificial Barriers in Superconducting Tunneling Junctions," by S. Celaschi, R. H. Hammond, T. H. Geballe, W. P. Lowe and A. Green, Bull. Am. Phys. Soc. 28, 423 (1983).

7. "Barrier Fabrication and Tunneling into Sputtered Multilayers of NbZr," by W. P. Lowe, S. Celaschi and T. H. Geballe, Bull. Am. Phys. Soc., 28, 508 (1983).

8. "NbZr Multilayers I: Structure and Superconductivity," W. P. Lowe and T. H. Geballe, submitted to Phys. Rev.

9. "NbZr Multilayers II: Extended X-ray Absorption Fine Structure Study," by T. Claeson, J. B. Boyce, W. P. Lowe and T. H. Geballe, submitted to Phys. Rev.

10. "Flux-Pinning and Inhomogeneities or Defects in Amorphous Superconducting Mo_5Ge_3 Films," by Shozo Yoshizumi, W. Carter and T. H. Geballe, to appear in the proceedings of the 5th International Conference on Liquid and Amorphous Metals, Los Angeles, (1983).

11. "Tunneling Properties of Single Crystal $Nb/Nb_2O_5/Pb$ Josephson Junctions," by S. Celaschi, T. H. Geballe, and W. P. Lowe, Appl. Phys. Lett. 43, 794 (1983).

12. "High Pressure Study of Some $ThCu_2Si_2$-Type Ternary Compounds," by P. H. Hor, X. C. Jin, M. K. Wei, T. H. Lin and C. W. Chu, T. H. Geballe, G. W. Hull, Jr., J. H. Wernick, R. L. Meng and Z. X. Zhao, submitted to AIRAPT IX, 24-29, July 1983, Albany, N. Y.

13. "Superconductivity in Ternary Heusler Intermetallic Compounds," by J. H. Wernick, G. W. Hull, T. H. Geballe, J. E. Bernardini and J. V. Waszczak, Materials Letters, 2 90 (1983).

14. "Towards and Understanding of the Limits of Superconductivity," by T. H. Geballe presented at the Distinguished Lecture Series, New Mexico Institute for Mining, New Mexico, October 20, 1983.

15. "Materials: Analogue Answers in a Digital Age," by T. H. Geballe, submitted to Physica.

16. "New Possibilities for Niobium-Based Josephson Tunneling," by S. Celaschi, T. H. Geballe, and R. H. Hammond, submitted to Journal of Applied Physics.

17. "Further Investigations of Solid-Liquid Interaction and High Field Critical Current Density in Liquid-Infiltrated Nb-Sn Conductors," M. Hong, D. M. Maher, F. Hellman, T. H. Geballe, J. W. Ekin, and J. T. Holthuis, submitted to the Applied Superconductivity Conference, San Diego, September 1984.

18. "The Effect of Non-Hydrostatic Strain on the Superconducting Properties of In-Situ Formed Cu-Nb_3Sn Filamentary Composites," by J. Beuk, W. A. Sunder, F. Hellman, and T. H. Geballe, submitted to the Applied Superconductivity Conference, San Diego, September 1984.

19. "Origin of the B_{c2} Enhancement in Ternary Nb-Sn Phases," by R. Bormann, D. Y. Yu, R. H. Hammond, A. Marshall, and T. H. Geballe, submitted to the Applied Superconductivity Conference, San Diego, September 1984.

20. "Thin Film Growth of Stable A15 Compounds," by F. Hellman, T. H. Geballe, Bull. Am. Phys. Soc. 29, 385 (1984).

21. "The Metal-Insulator Transition in Amorphous Molybdenum-Germanium Alloys," by S. Yoshizumi, D. Mael, and T. H. Geballe, submitted to the International Conference on Heavy Doping and the Metal-Insulator Transition in Semiconductors, U.C. Santa Cruz, CA, 30 July - 3 August 1984.

22. "The Specific Heat of Niobium-Zirconium Multilayers," by P. R. Broussard, D. Mael and T. H. Geballe, Submitted to Physical Review.

VISITORS AND SEMINARS

1. Dr. M. Gurvitch, Bell Laboratories
"Boltzmann Transport and the Saturation of Electrical Resistivity
October 6, 1983

2. Dr. Gloria Lubkin, Editor, Physics Today
"The Search for Stories: The Stories for Search"
October 26, 1983

3. Dr. Jim McGroddy, IBM, Yorktown Heights
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4. Dr. Gerd Binnig, IBM Zurich Research Laboratory
"Scanning Tunneling Microscopy, an Atomic Surface Probe"
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"Nuclear Weapons: Defense vs. Deterrets"
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8. Dr. James Boyce, Xerox, Palo Alto
"Microstructure of Random Solid Solutions: EXAFS Studies"
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9. Dr. Richard Koyama, Tektronix Inc. Beaverton, Oregon
January 5, 1984

10. Dr. Clyde Kimball, Northeastern University
January 5, 1984

11. Professor Rudolf Peierls, Oxford University, ENGLAND
"Momentum and Pseudo-Momentum"
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12. Dr. Gordon C. Osbourn, Sandia Laboratories
"Strained Layer Semiconductors"
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13. Professor M. Brian Maple, University of San Diego
"Superconductivity, Magnetism and a Possible New Superconducting State"
January 11, 1984

VISITORS AND SEMINARS (Cont.)

14. Dr. F. DiSalvo, Bell Laboratories
"Non-Linear Charge Density Wave Properties of Potassium Molybdenum Bronze ($K_{0.3}MoO_3$)"
February 2, 1984

15. Dr. Bernardo Huberman, Xerox PARC
"Dynamics of Computing Structures"
February 15, 1984

16. Dr. John Rowell, Bell Laboratories
February 12-23, 1984

17. Dr. Jene Golovchenko, AT&T Bell Laboratories
"X-ray Wave Optics at 1 Å"
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18. Dr. R. Becker, AT&T Bell Laboratories
"Alice in Wonderland: Atomic Surfaces Imaged with AT&T Bell Labs Tunneling Microscope"
March 9, 1984

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"Recent Advances in Synchrotron Radiation Research"
March 14, 1984

20. Dr. A. Kapitulnik, University of California, Santa Barbara
"Percolation Processes in Thin Films"
March 12, 1984

21. Dr. J. Orenstein, AT&T Bell Laboratories
"Photogenerated Excitations in Conducting Polymers"
March 15, 1984

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Member, Editor for Materials Letters, North-Holland Publishing Company, The Netherlands

Member, Committee for the American Physical Society International Prize for New Materials

Member, Advisory Board of the Miller Institute for Basic Research in Science

Scientific projects are being carried out in close collaboration with industry.

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V. Rehn, Naval Research Lab., China Lake, CA

New Discoveries, Inventions or Patent Disclosures

NONE

Persons Working on Contract During the Period
1 October 1983 - 31 March 1984

Hammond, Robert H.	Senior Research Associate
Hellman, Frances	Ph.D. expected Fall 1984
Mael, David	Ph.D. expected Summer 1985
Yoshizumi, Shozo	Ph.D. expected Summer 1985
Broussard, Phillip	Ph.D. expected Summer 1985
Park, Sung	Ph.D. expected Summer 1986
Kent, Andrew	Ph.D. expected Summer 1986